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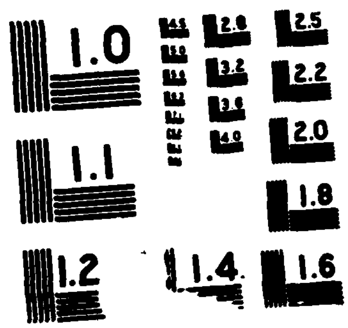
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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

THE F-100 SPARE PARTS SHORTAGE OF 1985: WHERE DID WE GO WRONG?

MAJOR JAMES M. MARG 88-1645

"insights into tomorrow"

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WHERE DID WE GO WRONG?

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This report looks at the history of the F-100 engine during the 1980-85 time period to determine the causes of the 1985 parts shortage. A brief overview of the F-100 engine history to 1980 is provided, followed by a detailed historical look at the events of the 1980-85 period. The F-100 engine is used in both the F-15 and F-16 aircraft, the main aircraft around which the US tactical air forces are built. Yet, despite the obvious critical impact a lack of these engines has on the USAF and on US military strength, the Air Force has run low on both engines and the parts to support them on several occasions. After an analysis of the parts shortages, the author draws several lessons learned that may prove useful to other system managers to prevent similar problems in the systems they manage.

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PREFACE

"Those who cannot remember the past are condemned to repeat it." In this quote, George Santayana produced the bottom line argument for those who believe it's important to study the past. When the past includes serious problems with the support of the primary United States combat aircraft, then we as members of the US Air Force should be especially concerned and eager to learn from it. For this reason this author chose to write about the F-100 aircraft engine, and specifically, the history behind the 1985 parts shortage.

The F-100 engine is used in both the F-15 and F-16 aircraft, the main aircraft around which the US tactical air forces are built. Yet, despite the obvious critical impact a lack of these engines has on the USAF and on the US military strength, the Air Force has run low on both engines and the parts to support them on several occasions since the initial purchase contract was awarded to Pratt and Whitney Aircraft on 1 March 1970 (1:31).

This report will look at the history of the F-100 engine during the 1980-85 time period to determine the cause(s) of the 1985 parts shortage. A brief overview of the F-100 engine history to 1980 is provided, followed by a detailed historical look at the events of the 1980-85 period. The author then analyzes this period to determine the causes for the parts shortages. Lastly, the author draws some lessons from the history and analysis for future system managers to use in hopes of preventing similar problems from occurring in their systems.

The author of this study has an advanced degree in Systems Management and over seven years experience in aircraft maintenance. However, due to time and research length constraints, he has simplified this complex situation significantly, making it much easier to understand without changing the lessons learned. This paper is most suitable for those people who have limited knowledge of the F-100, but desire to learn about the engine's history and the problems experienced with it.

Additionally, users of this paper should note that many of the sources cited have an overall classification of SECRET, however, THIS REPORT CONTAINS NO CLASSIFIED OR "FOR OFFICIAL USE ONLY" INFORMATION. All data has been carefully screened to ensure this report contains no classified information.

CONTINUED

Lastly, the author wishes to thank all of the people who helped so much with this project. Thank you to Lt Col Michael H. King, former F-100 Engine Propulsion System Manger for all the data and insight he provided, and likewise to Mr. Ed Brewer from the San Antonio Air Logistics Center for the data he provided. Also, thanks to Mr. Donn Sinclair, Local Representative for Production Support, Pratt and Whitney Aircraft, San Antonio, TX. And finally, a special thanks to my advisor, Major Phillip Miller, who not only helped me stay on track but, kept me from abandoning what turned out to be a very complex subject to research.

ABOUT THE AUTHOR

Major James M. Marg graduated from the United States Air Force Academy on 2 June 1976, with a Bachelor of Science Degree in Management. He entered Undergraduate Pilot Training (UPT) at Vance AFB, Oklahoma, and after graduation went to Castle AFB, California, for B-52H training. He arrived at K.I. Sawyer AFB, Michigan in July 1978, where he was assigned to the 410th Bombardment Wing. After flying the B-52H for about one year, Major Marg was medically grounded and transferred to the 410th Field Maintenance Squadron, where he served as the Assistant Maintenance Supervisor until November 1981. Major Marg was next assigned to the 380th Bombardment Wing at Plattsburgh AFB, New York. There he served as the Maintenance Supervisor in both the 380th Field Maintenance and Organizational Maintenance Squadrons, as well as the Officer in Charge (OIC) of the Bomber Branch. In July 1984, Major Marg was assigned to the 11th Strategic Group, Royal Air Force (RAF) Fairford, England. There he served in the 11th Consolidated Aircraft Maintenance Squadron (CAMS) as OIC of the Avionics Maintenance Branch and then the Organizational Maintenance Branch, before being selected as the CAMS Maintenance Supervisor. He served in that position until July 1987. In August 1987, Major Marg was assigned to Air Command and Staff College, Maxwell AFB, Alabama.

Major Marg has a Master of Science Degree in Systems Management from the University of Southern California. He has completed Squadron Officer School in residence, and is currently completing Air Command and Staff College. His decorations include the Air Force Commendation Medal, and the Meritorious Service Medal with one Oak Leaf Cluster. Major Marg is married to the former Sondra Forstrom of Winona, Minnesota. They have two children, Christopher and Elizabeth.

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EXECUTIVE SUMMARY

REPORT NUMBER 88-1645

AUTHOR(S) MAJOR JAMES M. MARG, USAF

TITLE THE F-100 SPARE PARTS SHORTAGE OF 1985: WHERE DID WE GO WRONG?

I. Purpose: The purpose of this study is to determine what factors led to the 1985 parts crises suffered by the F-100 engine system. This is accomplished by performing a historical analysis of the F-100 engine, specifically concentrating on the 1980-85 time period. A secondary purpose of this report is to provide lessons learned from the analysis of the history that led to the parts crises.

II. Problem: No history of the F-100 engine or the problems experienced in the upkeep of this system exists in one convenient file. The only history presently available is scattered in numerous documents, with only pieces of that history in each document.

III. Data: The F-100 engine has been plagued by problems since it entered the inventory in November 1974 along with the aircraft it first powered, the F-15. The initial problems were related deficiencies in the design of the engine. They included problems with engine stall/stagnation, turbine blade failure, thermal cycles, and associated problems of less serious nature. These problems seem to be corrected or well on their way to being corrected by 1980. Then, however, a second problem period begins, a period this author has broken into three phases. The

first phase covers the period from 1979-1982. This phase focuses on Congressional concerns and the actual corrections performed to fix earlier problems. The second phase, from 1982-1984, covers the period when the system is in transition. During this period the emphasis shifts from procuring the needed parts as quickly as possible, to procuring them as cheaply as possible. The third phase, from 1983-1985, examines the results of the massive changes to the procurement system and its impact on parts availability. The major impact being, an increase in parts acquisition time.

IV. Conclusions: This study concludes that the F-100 engine was plagued by multiple problems for numerous reasons. The engine design significantly pushed the state of the art when initially developed. The whole design program was pushed to meet the perceived Soviet threat. Additionally, the huge increase in engine thrust and responsiveness led the crews to fly the engines differently than any other. This resulted in a higher engine cycle rate than expected, as well as more stress on the engine than anticipated. Furthermore, the process to manage the engine was made even more complex by the fact that the F-100 engine was the first modular designed and maintained engine. This fact, combined with mandated increases in the competition process for procuring spare parts, made parts forecasting very difficult. All of these factors combined in a synergistic fashion in late 1984, and culminated in the 1985 F-100 parts crises. Lastly, the very critical role the F-100 engine plays in the tactical air forces of the United States makes this subject worthy of considerable review and study. Other complex systems like the F-100 will surely be part of the Air Force in the future. For this reason, it is important to understand what happened with the F-100 engine in order to prevent a repeat in another system.

Chapter One

THE EARLY YEARS OF THE F-100 ENGINE

OVERVIEW

The Need For The F-100

Clearly, the development of the Pratt and Whitney F-100 engine was the result of a perceived threat to our tactical air forces that occurred in the mid-1960s. Specifically, in July 1967, the Soviets unveiled 12 new and advanced military aircraft in their first airshow in six years. Two of those aircraft, the MiG-23 Flogger and MiG-25 Foxbat, were perceived as superior to any fighter the United States had either in its inventory or approved for development and acquisition (1:10). This airshow not only got the attention of the Air Force, but also of Congress. The Air Force felt, and Congress agreed, the US needed to field a superior fighter by the mid-1970s, or we would allow the advantage to pass to the Soviets. "The evidence suggested almost certain Soviet air superiority in the mid-1970s and beyond unless, of course, the USAF could develop and deploy a counter to the anticipated Soviet threat" (1:1). The race was on. Our goal--field a superior fighter by the mid-1970s.

The Development Goals

Despite a rather well-defined goal of fielding a fighter superior to the Soviet threat by the mid-1970s, the actual path

and the equipment needed to get us there lacked definition. The mid-1960s was a time of considerable change and controversy. Besides the Vietnam War, there was Robert S. McNamara and his "whiz kids." Certainly, almost everyone today remembers him for introducing the concepts of "systems analysis" and "cost-benefit ratios" into the vocabularies of the Air Force and Congress. It's no wonder that it took from January 1965, when "the idea of the F-X [later to be designated the F-15] had been formalized" (1:12), until March 1970, when "Pratt won the contract . . . to design, develop, and test the F-100 engine for the Air Force" (1:31) to define the desired product. To be the best fighter in the world, the F-X would need the best engines in the world. At a time when the best engines had a thrust-to-weight ratio of 4-to-1, the engines to power the F-X would have an 8-to-1 ratio. Although this required performance level was on the very leading edge of both our design and production capability, it became the goal. This lofty goal would later contribute to the F-100 engine problems.

The Pre-1980 Problems

The fact that the F-100 engine was developed based on leading-edge technology led to many of the early problems. The first difficulties occurred during engine development. Pratt and Whitney had considerable problems getting the engine to produce the required thrust while sustaining the resulting stresses on the engine components. The fan and turbine blades were especially troublesome, actually leading to the failure of the

first Military Qualification Test (MQT) on 26 February 1973 (1:39). The engine finally met reduced MQT standards in April 1973, and entered operational service in the F-15 at Luke AFB, Arizona, in November 1974 (6:81).

The F-15 and its F-100 engines were welcome additions to the Air Force in 1974. From all indications, the pilots were pleased with the aircraft and its performance. However, by July 1977, several severe problems began to appear. The two main problems were stall/stagnation and turbine blade failure, while a third problem, thermal cycles, were both a result of and contributed to the two main problems.

The first major problem identified was engine stall/stagnation. This occurs when the engine compressor blades stall aerodynamically because of either external or internal disturbances in the airflow through the engine. As a result, the engine loses thrust as the airflow decreases, but the temperature in the engine goes up significantly. The only way to recover the engine is to shut it down and restart it (6:3). This obviously not only limits the usefulness of the engine and the aircraft it powers, but drastically reduces the margin of safety associated with the engine and its overall life.

The second major problem was turbine blade failure. With the great speed at which the turbines rotate, this problem is particularly serious because a blade failure often meant catastrophic damage to the engine and even worse, to the aircraft. The primary factor behind these failures was

overtemperature stresses, with the majority of the overtemperatures directly related to either overheats during engine stall/stagnation, or to the uneven heat patterns that developed in the engines during the stall/stagnation. So significant was the problem that fully "seventy-five percent of the first 54 turbine failures were attributed to overtemperature stresses" (1:64). Also contributing to this problem, as well as reducing overall engine life, was the factor of thermal cycles.

Thermal cycles, or engine cycles as they're commonly called today, were found to be much more important to engine life than many had previously thought. An engine cycle (defined as taking the engine from a low to moderate power setting to a high setting and back to a low setting) was found to have a greater impact on the engine's life than the number of operating hours. This is significant for several reasons. First, as this wasn't determined until after the F-100 engine was developed, it was not incorporated into its design. Secondly, it was not a part of the MQT, nor was it included anywhere in the engine design criteria (1:58-60). Additionally, "neither Pratt and Whitney Aircraft nor the Air Force realized at the time the engine criteria were established that the F-X fighter's thrust-to-weight ratio would result in tactics which would significantly change the F-100 engine mission profile" (6:89). The actual flight data gathered from this time period showed engine cycles to be six times higher than expected--an obvious impact on engine life.

Other engine problems included 40 main fuel pump malfunctions that resulted in 26 single-engine landings by the F-15 during 1977 (1:65-66). While in 1979, about 50 percent of the unscheduled maintenance manhours were spent on afterburner problems, a full 65 percent of this unscheduled labor was spent working the engine's external titanium nozzle flaps (1:66). As 1979 drew to a close, we find the US Senate becoming interested in the F-100 Problems.

The best way to sum-up the 1970s and move into the 1980s is to examine the report of the US Senate Committee on Armed Services which met on 27 November 1979, to look at F-15 and F-16 engine problems. This report highlights what went on in the 1970s, provides a look at the current situation, and makes a projection as to when the problems would be resolved.

Chapter Two

THE F-100 ENGINE COMES OF AGE

Congressional Interest

The history of the F-100 engine parts problems during 1980-85 can be best understood by breaking this period into three distinct, but overlapping phases. Phase one covers the period from about 1979-1982. This phase is marked by congressional concern over the resolution of the F-100 parts problems, and by continuing efforts to resolve the problems discovered in the 1970s and early 1980s. By 1982, despite continuing parts shortages, there is a move away from the part shortage concerns to a phase where the cost of spare parts becomes the major concern. Phase two is thus the transition from about 1982-1984. During this time, the cost of the part and fostering competition seem to become more important than whether the part was available, or how qickly it could be provided. This phase in turn leads to the next phase where parts shortages are again the main concern. Phase three, the period from 1983-85, is marked by parts shortages created in large part by the very procurement and management system the Air Force adopted in phase two. With this structure in mind, this chapter looks at the congressional concern in phase one.

Congressional Interest Aroused

Because of the continuing problems with the F-100, and because this engine was so critical to national defense, Congress was extremely interested. On 27 November 1979, General Alton D. Slay, Commander, Air Force Systems Command (AFSC), and Mr. William Missimer, Executive Vice President, Government Production Division, Pratt and Whitney Aircraft, were principle witnesses for the US Senate Committee hearing held to investigate the F-100 engine problems. Senator Howard W. Cannon presided over the hearing, and according to him, the reason for the hearing was ". . . the potential gravity of the situation affecting the readiness of the Air Force . . ." (6:2). Additionally, Senator Cannon desired to review the proposed recovery plans, and to be assured on how the Air Force would apply the lessons learned from this situation to future engine programs.

Problems and Fixes

In the recovery plans, Gen Slay addressed three problems, stall/stagnation, turbine blade failure, and the under estimation of spare parts required. The stall/stagnation problem, addressed first, was overcome by three specific engine modifications. The first two changes affected the afterburner settings upon the detection of a stall. By "reducing afterburner fuel flow to minimum and opening the afterburner nozzle . . ." (6:3), the back pressure was removed and the compressor wouldn't stall. A third modification was only made to the F-100 engines used in F-16 aircraft. This was the installation of a "proximate splitter" to

further reduce the tendency for afterburner pulses feeding back and stalling the compressor by reducing the clearance between the fan exit and the compressor and associated bypass ducts (6:3-4). This third fix was viewed as necessary only for the F-16 because the F-15 already had an expanded safety margin over the F-16--two engines instead of the single engine in the F-16.

The second problem addressed was turbine blade failure. General Slay called this "the most serious durability problem . . ." (6:4). Several actions were under way to correct this problem. The modifications made to the engines to reduce stalls/stagnations helped by reducing the overheating and uneven temperature distribution. In addition, there were improvements made to the turbine blades themselves. Most importantly though, they were ". . . able to eliminate impending turbine failures in the operational force by inspecting the turbines using a flexible, fiberoptic borescope . . ." (6:4). By inspecting the F-16 engines every 50 hours and the F-15 engines every 100 hours, they could find and eliminate the problems before failure. The result, however, was an increase in the workload and parts needed because of the engine teardowns required to replace blades not up to standards.

The third problem General Slay stated was that "we had clearly underestimated our logistic support requirements for the F-100 engine" (6:4). He saw this as a result of basing the need on the number of hours on the engine, not on the number of cycles. (An engine cycle was defined as a throttle transition

from low to moderate power up to a high power setting and back to low or moderate power.) Further, greater component distress than predicted was found when the engines were opened for inspection (6:4). For example, the projected condemnation rate for the first stage turbine vanes was 20 percent--the actual rate in FY 1980 was 33 percent (13:91). Additionally, beside erroneously projecting the parts required based on hours of operation, as was traditionally done on engines, the Air Force realized the number of engine cycles was more important and this factor had also been significantly underestimated (6:4). This served to compound the parts shortages, and required intensive efforts to resolve the situation.

One of the most significant actions taken was to implement ". . . the Department of Commerce managed defense priorities system" (6:5). This action gave priority to the materials and components needed by the F-100 engine vendors, and was expected to increase production by 75 engines in 1980 (6:5). Additionally, the F-100 engines were all tuned to lower engine operating temperatures, cooling them by 80 degrees Fahrenheit and further reducing heat induced stress (6:4). All these actions were expected to help, but the future still looked rather uncertain.

Projecting The Future (from 1980)

As 1979 drew to a close and 1980 got under way, serious problems faced the F-100 managers. Despite involvement by the Commerce Department to aid F-100 vendors, as many as 40 F-15

aircraft faced possible storage because there were no engines available (7:620). Although the Commerce Department action gave priority to the F-100 vendors to procure raw materials that were in short supply, such as titanium, waspalloy, and cobalt (13:90), it could not resolve the lengthy time periods required to produce the parts. For example, first stage turbine blades had a 29-month acquisition time (13:90), and even the smallest forging now takes ". . . some 27 months, whereas it used to be three months" (18:11). Furthermore, because the F-100 engine requires a major depot inspection at 1350 hours, it appeared that ". . . a whole fleet of aircraft [engines] were approaching a maintenance milestone without the necessary parts" (13:91). Despite all these problems, recovery was projected for mid-1981 (6:5).

Reality (1980-1982)

It took significant action by everyone involved to keep F-15s and F-16s from being severely impacted by the F-100 engine shortages. A program called "Have Swap" used engines from F-15s going to the depot for modifications to prevent new F-15s being produced from immediately being placed in costly storage by the manufacturer (1:86; 7:620). Additionally, 11 depot field teams were sent to various bases to help them with their engine spare rate (7:623). The number of spare parts required was increased to meet the higher demand rates being experienced, yet they realized "many of the spare parts being ordered in 1980 would not reach the Air Force for several years. . ." (7:632).

The actions taken eventually worked to reduce the problems. Certainly there were still problems during and beyond 1982, but "the number of total net spares improved significantly and by January 1982, there were 35 F-100s for the F-15 aircraft and 21 for the F-16 aircraft--a record number of spare engines for meeting TAC's [Tactical Air Command's] requirements in the past two-and-a-half years" (14:56). Everyone seemed to realize the F-100 would always take extra effort to manage, but by the close of 1981 it looked like things were back under control. It's about this time when a new problem comes on the scene, taking attention away from the F-100 parts shortages and focusing on the cost of those parts.

Chapter Three

THE SYSTEM IN TRANSITION

Spare Part Costs--The Need for Competition

During the period 1982-84, the Air Force underwent a major transition in the way items were procured. As early as March 1981, a study had been conducted on how the Air Force should purchase spare parts. Whether parts were bought from the prime contractor for the system, or from the manufacturers that made the parts directly, little had been done to change the acquisition system. Up until 1981, more attention had been paid to the fact the Air Force was often dependent on only one or two manufacturers for many critical parts. The strikes in April 1979 at a bearing manufacturer and a forging contractor directly impacted the production of F-100 engines. It seemed "the strikes reemphasized the precarious nature of F-15 and F-16 total dependence on one manufacturer and one engine to meet all the high-performance needs of the tactical air forces" (1:85). Even in July 1981, when then-Deputy Secretary of Defense Frank C. Carlucci issued a memorandum on the need to increase competition, it stressed that competition ". . . reduces the cost of needed supplies and services, . . . [and] . . . increases the industrial base" (15:7). Richard D. Delauer, then-Under Secretary of Defense, Research and Engineering, went so far as to "direct each military

department and defense agency to designate individuals at each procuring activity who are advocates for competition. . ." (15:7). Competition was seen as necessary for cost reduction, and just as importantly, to improve the industrial base so the Air Force would not be dependent on one source of supply. In 1982, however, all of this changed with the "help" of one man at the Oklahoma City Air Logistics Center (OC-ALC), Robert S. Hancock.

The Hancock Letter--A Big Push for Competition?

The Air Force leadership did a good job in determining the need for competition, but didn't do so well really making it an effective program in the field. As a result of Under Secretary of Defense Delauer's directive, Assistant Vice Chief of Staff of the Air Force, Lieutenant General Hans H. Driessnack, directed "Air Force activities to have competition advocates in place by 1 May 1982" (15:8). Consequently, the San Antonio Air Logistics Center (SA-ALC) established a competition advocate function in spring 1982. But, this function did little ". . . in the area of competition advocacy at SA-ALC in 1982" (15:8). In July, however, the Air Force finally got serious.

In July 1982, Robert S. Hancock, an employee at OC-ALC, wrote in a letter that he had ". . . found 34 engine parts whose price had quadrupled in two years" (1:115). This letter led to a cry of outrage by both the Congress and the public (5:115-116). With so much pressure and attention focused on the parts cost problem, the Secretary of the Air Force directed the Air Staff to

study the total parts procurement process. In September 1982, Secretary of Defense Caspar W. Weinberger "reiterated the administration's views on competitive procurement and directed all Department of Defense components to place maximum emphasis on placing contracts on a competitive basis whenever possible" (15:18). This led General James P. Mullins, then-Commander of Air Force Logistics Command (AFLC), to again encourage competition by stating on 9 December 1982, "I have reassessed our current effort in this area and I am not satisfied with our progress" (15:11). By 1 February, SA-ALC had its separate office of Competition Advocate with Joseph Hollaway, who had 20 years experience in management and acquisition, as its first chief (15:12).

Results--Competition, but with Problems

Competition was here to stay by late 1983, but with it came many unanswered questions and new problems. An AFLC-wide meeting of the Competition Advocates in September 1983, highlighted concern over the important subject of ". . . who would be the final authority on the [selection of the] Acquisition Method Code (AMC)" (15:17). This was of considerable interest because some felt establishing an AMC, which determined if a part would be bought competitively or sole source (i.e., from a single, historically reliable vendor), should be determined by the Competition Advocate based on the need to enhance competition. Others, especially the Directors of Material Management who were responsible for engine production, wanted this code established

not only with competition in mind, but also dependent on the criticality of need. The final agreement called for the Competition Advocate to have the final say, but not without coordinating the code assignment through Material Management. If they couldn't agree, the decision would then go to the SA-ALC Vice Commander for resolution (15:16-17).

But just deciding to buy the parts competitively wasn't enough. Vendors capable of making the parts had to be found, and before approaching sources other than the prime contractor, the Air Force first had to contact the prime contractor for the data to procure the parts. The prime contractors, however, were reluctant to do this, considering the data as ". . . proprietary and unavailable for sale, except at exorbitant costs" (1:116). The Air Force was thus often left to prove the data was not proprietary, a process that takes considerable time and people to accomplish. With existing shortages of people to do the job, the lead time to procure parts continued to grow. To make matters worse, on 18 July 1984, Congress enacted Public Law 98-369, the Competition in Contracting Act (CICA), which further dictated much of the procurement process. Already in the first half of 1983, the engine spare status was on a downward trend with greater than anticipated parts usage (8:465). Now, the Congress had forced the Air Force into ". . . acquiring its spares slow and cheap" (5:119), closing this phase with the system in deep transition.

Chapter Four

OLD PROBLEMS SOLVED--NEW ONES CREATED

Phase three, the period from late 1983 through the actual parts crisis in 1985, is marked by a general renewal of interest in the actual parts shortages the F-100 suffered, but always with competition in mind. No historian could review this period of time without mentioning the impact of competition on the parts shortage. This is not to say all the problems with the F-100 engine had been solved, only that almost any problem whether old or newly discovered, now tended to be compounded by what can be described as "the need to be competitive."

Tensions with Pratt and Whitney

Because Pratt and Whitney was the prime contractor for the engine, many people blamed them for the problems. Over time, this attitude led to strained relations between the Air Force and Pratt and Whitney. With the concern over the cost of spare parts growing, and knowing rightfully or not many were blaming Pratt and Whitney, in March 1983, a request for proposal was released. The purpose of the request was to begin ". . . competition for a fighter engine with better reliability, maintainability, and supportability than the current F-100 engines being used on the F-15 and F-16" (8:354-355). This competition for an improved engine became known as the Alternate Fighter Engine competition.

The significance of the Alternate Fighter Engine (AFE) competition to the 1985 parts crisis is limited. It is noted here because it is indicative of the extent to which the Air Force was now willing to go to promote competition. What the AFE competition did was focus attention on the F-100 problems. Numerous press references were made to ". . . the Air Force's hard-learned philosophy that engines should be reliable first and powerful second" (8:358). Additionally, when Pratt and Whitney finally realized how significant the necessity for competition was, they took action to improve the reliability of their engine as well as offering better warranties. In fact, "the new engines were warranted to be twice as durable as the then-current F-100, . . ." (1:128).

It should be noted these actions by Pratt and Whitney came only after they felt their continued resistance to the AFE competition was useless. The February 1984 announcement by Secretary Weinberger of a split award between Pratt and Whitney and General Electric (1:126), was the real point of no return for Pratt and Whitney. Of the 160 engines ordered for FY 1985, only 40 (25 percent) would be awarded to Pratt and Whitney (1:126). Their monopoly on the Air Force fighter engine program was broken, and things would never be the same.

System Overload

With the drive for competition continuing, and many of the F-100 engines reaching their first major depot inspection/repair point, 1984 became a year of tremendous work loads. As stated

earlier, 1983 already marked a decline, with F-100 supportability ". . . marginal and the workload of all TAC units excessive" (8:464). But, it was in 1984 when "in the critical area of engine production, efforts to control the prices of spares seemed to boomerang on AFLC officials" (10:117).

In 1984, at least eight briefings were presented by SA-ALC to a variety of audiences from the Commanders of Pacific Air Force and 9th Air Force, to members of the F-100 Readiness Working Group (12:--). All of these briefings highlighted both the impact of competition and an increase of Economic Order Quantity (EOQ) part shortages. (EOQ parts are normally of lower value so as to be ordered in bulk quantities, such as bolts or washers, as opposed to more costly parts that are order as required.) By late 1984, the number of required EOQ parts accounted for ". . . approximately 50 percent. . . [of the parts]. . . on the field and depot parts shortage list. Formerly, EOQ parts accounted for only 10-15 percent of the shortage items" (12:--). Two factors seemed to be driving this situation, competition and poor forecasting.

Competition--Curse or Blessing

Just as the managers at SA-ALC had predicted, spare parts became a crisis item in 1985. From January to May 1985, the number of serviceable spare F-100 engines for the F-15, dropped from 64 to only two (11:--). Interestingly, the F-100 engine Readiness Working Group had stated the cause in November 1984, when they identified ". . . spare parts as causative in the

shortfall of serviceable F-100 spare engines" (5:117). So why, if everyone knew the crisis was coming, did it still occur? The answer lies largely in the acquisition system which had been changed by competition, and in the system that failed to recognize the change.

While the acquisition system had changed, many of the people involved with ordering the spare parts had failed to comprehend the changes or impacts of those changes. Many of them were used to working with Pratt and Whitney, who, despite what some in the Air Force felt, had worked to resolve known parts shortages. Lieutenant Colonel Michael H. King, F-100 Engine Program Manager, SA-ALC, explained well what had happened:

> Until recently the true magnitude of this problem has been masked by a Management Critical List (MCL). . . [which Pratt and Whitney used]. . . to identify and accelerate delivery of potentially critical parts. The MCL, which formerly contained 300 parts, has been reduced to approximately 50 because of the breakout of parts procurement away from Pratt and Whitney to other vendors. Most breakout vendors do not have the capital and business base to accelerate deliveries as Pratt and Whitney did (16:--).

The same thoughts were echoed in a 6 May 1985 Aviation Week and Space Technology article (3:17). It seems the truth was that Pratt and Whitney had, at least on some issues, worked with the Air Force to resolve the parts problems affecting the F-100, but now, they were denied from doing so by new competition laws. The cost of using other vendors was now being realized.

Poor Forecasting--A Factor Compounding the Problem

The spare parts shortage was compounded by poor forecasting of the required parts in a timely manner. Too many people had become accustomed to working on the edge of the system, not worrying about the overall system, only the "problem parts." But, now the whole system had changed and "some of the parts require[d] a year or more to acquire" (3:16). From 1983, the average time to procure F-100 spare parts had gone from 58 days to 159 days in 1985 (3:17), and the people just hadn't ordered parts soon enough.

Additionally, when the parts were finally ordered, because of the way the acquisition system was built, the high cost items tended to be bought first so the system could show 85 percent commitment of funds in the first 10 months (12:--). This meant the smaller cost parts (generally EOQ) didn't get ordered until after the other items (11:--). The obvious result was highlighted by Air Force deputy Assistant Secretary for Logistics and Communications, Lloyd K. Mosemann, when he said, "Frankly, it is the small parts that have gotten us into the most trouble" (3:17).

Another factor influencing poor forecasting was the computer management system product (D062) used to forecast needed parts, many of which were EOQ parts. Based on the consumption history of the last eight quarters (a quarter being three months), the system would project future need. The trouble was when engine production dropped for any one component over a period of a

quarter or more, the system would "see" the reduction in overall parts demand and would start to forecast lower requirements. The result was eloquently termed "an EOQ death spiral--buying fewer parts in response to decreasing production that in itself was caused by insufficient earlier bit and piece support" (11:--). The only way out is to make manual corrections to the computer system but, it takes time and talent to figure the true need for the multitude of parts an F-100 requires. Because time in the F-100 business is always in short supply and the talented people overloaded, the system often didn't get the correction. More often, the problem parts were not even recognized until the supply bins were empty. This whole problem first came to be understood in 1985, but by then the production problems resulting from the part shortages were upon them (11:--; 12:--).

Other Factors Affecting the Parts Shortage

Certainly the procurement process, as affected by competition, and poor forecasting weren't the only factors to impact parts availability. Other problems included everything from simple human error in ordering parts (entering wrong stock numbers into the system), to newly discovered wearout and failure modes in the engine, to problems with some of the vendors who had won under the competitive bidding system, but then failed to produce quality parts in a timely fashion (3:16; 4:19). The Tactical Air Command had also experienced continued reduction in thrust from the engines, and in 1984 retrimmed the F-100s back to 98.5 percent (9:319). Although they feared significant part

shortages from this action, the retrim only "highlighted known engine deficiencies but did not find new problems caused by operating retrimmed engines" (9:319). As the Readiness Working Team indicated, the concurrency of the problems had a detrimental synergistic effect that severely impacted F-100 support (11:--).

The combined effect of the multitude of problems all came to a head in 1985. Specifically, in May 1985, an Aviation Week and Space Technology article, "Half of USAF's F100 Engines in Spare Inventory Unuseable" (3:16), highlighted the sad state of affairs. The May 1985 spare parts/engines crisis closed phase three, and with it a multitude of problems, many of which originated from "forced competition." All combined to degrade the Air Force parts supply to the F-100 engine. Having reviewed the history of the F-100 engine and the associated parts shortages, especially during the period from 1980 to the May 1985 parts crisis, the next section contains the analysis of the crisis, draws some lessons learned, and looks at some things that still need to be worked in the future.

Chapter Five

ANALYSIS--LESSONS LEARNED--A LOOK TO THE FUTURE

Looking at history without analyzing it and applying lessons learned to the future may be enjoyable, but is of no practical value. As George Santayana said so eloquently, "Those who can not remember the past are condemned to repeat it." In the Air Force, with our vital mission of national defense, we can not afford to make the same mistakes again. For this reason, it is important to look at the F-100 problem and draw some lessons. Although this paper has had to greatly simplify a very complex and difficult problem, it retains enough of the essence and history of the problem to allow analysis and the drawing of lessons for future use. This is the objective of this chapter.

Causes of the Crisis

Two root causes of the F-100 part shortages are the development process used for the F-100 engine and the maintenance concept of a modular engine. From the very beginning, when the Air Force released its request for the engine, it failed to consider several key factors. By concentrating on the engine thrust required, the Air Force overlooked durability and reliability (2:52; 6:5). Additionally, because the Air Force failed to perceive how the increase in thrust available would

change tactics, new stresses were put on the engine (6:84, 89-90). The Air Force did not understand the significance of engine cycles until after the F-100 was deployed (6:89-90). When the engine problems were finally realized, there was little the Air Force could do but resort to a Component Improvement Program (CIP) to slowly improve the engine by identifying troublesome parts, and then building better, more durable parts to replace the bad ones (2:52).

This program caused its own problems though. The CIP program takes time and manpower, and can impact engine management. For example, it affects engine production when troublesome parts are taken off the line and rebuilt or improved. Additionally, under the modular engine concept, where an engine is made up of several modular sections like the F-100 is, it is important to build up engines out of equal cycle modules. If not, then later increases in work occur when the engine has to be removed from the aircraft and broken down to replace a module that is due for inspection or replacement before the rest of the engine. This takes both manpower and parts, but is exactly what the CIP program often introduced. Because of the many improvements being made, there quickly was a fleet of modules in various phases of modification which required even more individual tracking to prevent a "wrong" match-up. Early module swaps to prevent or correct module mismatches in an engine cost parts and manpower. Even when "out of cycle" module swaps kept the engine module cycle even, the swaps created surges and lulls

in the demand for parts. This whole process took some time to learn as the F-100 engine was the first to use the modular concept (17:--; 11:--). Even when it was eventually understood, it still impacted the demand for parts which in turn caused fluctuations in the supply system and made the forecasting of parts difficult.

If forecasting part requirements wasn't hard enough, the introduction of large scale competition added to the difficulty. After breakout from the prime contractor, parts took longer to get. And when they did arrive, they were sometimes of inferior quality. Other times, the contractor who initially won the bid later found out he simply could not produce the part, and the contract award cycle process had to be repeated. In the mean time, the engine part supply suffered and the number of available spare engines dropped. Furthermore, as the workload fluctuated at the depot due to part shortages, it added to the forecast problems and induced erroneous usage rates into the supply computer system which bases need on consumption history. This further complicated the situation.

Additionally, because breaking the parts out from the prime contractor and finding and awarding the contract to another vendor takes time and people, system overload developed. Priorities were established, often with high cost parts getting the attention. This created more problems when the low cost parts (EOQ) which had been ignored, didn't get bought on time, causing work stoppages in the spare engine production line.

Certainly increased competition lowered the cost of spare parts over time, but it was at a cost in the readiness of the system. Despite it all, the Air Force learned valuable lessons from the many problems faced while trying to support the F-100 engine.

Lessons Learned

Many lessons can and have been learned from the problems associated with the F-100 engine. In November 1979, while appearing before the US Senate Committee on Armed Services, General Slay, then the AFSC Commander, identified several lessons the Air Force needed to learn (6:5). High on his list was that engine development must precede aircraft development. As engines take longer to bring on-line, to try to develop both together, as the Air Force did with the F-15 aircraft/F-100 engine, only leads to short-changing one system or the other. Second, General Slay said more emphasis should be placed on durability and maintainability. Third, he indicated the test programs must test the system under realistic operational conditions and use. Fourth, he said the development and maintenance of second sources for critical components was necessary. Tied to this point was the need for competition to keep the price of spares low while maintaining a production base. Finally, he stressed conservative planning, meaning in this case to expect delays and problems in the procurement of spares (i.e., not to plan such a tight schedule that the unexpected will have a detrimental effect). This author believes all of these points to be just as valid today.

In addition to the lessons General Slay highlighted, several more seem appropriate. One the author believes is essential is to educate each individual in the system to know not only his or her job, but also why it is important, and the impact of their on-the-job performance on the total system. Clearly, it is important for each individual to understand the goal. For example, maintenance orders a part on priority, supply expends the extra effort and funds to deliver the part expeditiously only to have it delivered by "slow boat" because transportation didn't understand the requirement. This creates a serious problem in the system. Someone didn't understand the goal. The same is true when high-value parts are acquired first because they're "more important" only to have production shutdown for the lower-cost EOQ parts. Everyone must be educated on the goal and the methods to get there so they can work as a team.

A second lesson the Air Force needs to learn and incorporate into its people is a tolerance for honest mistakes and in conjunction with this, to be more willing to accept corrections. More willingness by both the Air Force and Pratt and Whitney to accept the "mistakes" in the early F-100 program, and then to work as a team to resolve them would have benefited both sides in the long-term. The same could be said of the supply/acquisition system that is reluctant to allow a change in the projected parts requirements because "it doesn't match the past demand." Again, full understanding of the goal and tolerance to corrections and changes could reduce Air Force operating costs while providing

better support. Somewhat related to the lack of tolerance to change, is another point--the lack of trust.

The author believes the whole military system has become highly suspicious of industry, and industry of the military. Serious efforts should be taken to resolve this issue. Because of our "corporate" lack of trust in Pratt and Whitney, and their lack of trust in the Air Force, tensions grew between the parties. This certainly didn't help get the problems solved any faster. Industry needs to feel free to deal with the military and be certain that they will make a reasonable profit. Likewise, the military must be able to trust industry to give a good product at a reasonable price. If problems occur in the development or production of a weapon system, trust would allow both sides to work more closely together to resolve the difficulties. It's in the military's interest to maintain a reasonable industrial base for weapons production, while industries want to stay in business. We ought to be able to trust each other and work together. Equally as true, the different military branches and sections within a single branch need to trust each other. The F-100 history indicates far too much distrust between different sections, different services, the Air Force and Pratt and Whitney Aircraft, and between Congress and the Air Force. The adversarial outlook is present far too often and needs to be resolved to improve the working relationships, and thus overall potential.

The last lesson is for both Congress and the Air Force (or military as a whole) to become more understanding of the complexity of the systems both must work in and through. Simply relating this to the F-100 situation, the Congress has to be more cognizant of just how large the acquisition system is and allow sufficient time for proposed changes to be implemented without adverse impact, while the Air Force needs to be as responsive to Congress as it can, while working to limit adverse impacts. The massive changes made to the acquisition system, despite being accomplished over several years, still occurred so quickly as to adversely impact the ability to procure parts to support the F-100 engine--an engine key to the US tactical air forces. To prevent a similar recurrence, every military member must try to understand and implement the directions of Congress, while continuing to work diligently to educate the Congress on the military needs and the consequences of any Congressional actions.

Looking to the Future

In taking a look to the future, only a few things need to be said. First, despite all the problems with the F-100 engine highlighted in this history, it remains one of the best engines in the world. This is true because of the people--good, hard-working people who met the challenges. People are, and will continue to be this nation's most valuable resource. New challenges will always be present, but if we as a nation can build trust, while maintaining tolerance, we can and will always meet and surpass all adversity.

BIBLIOGRAPHY

A. REFERENCES CITED

Books

1. Drewes, Robert W. The Air Force and the Great Engine War. Washington, DC: National Defense University Press, Government Printing Office, 1987.

Articles and Periodicals

2. Bond, David. "Double Trouble?" Military Logistics Forum, April 1985, pp. 50-54.

3. Marsh, Alton K. "Half of USAF's F100 Engines in Spares Inventory Unusable." Aviation Week and Space Technology,.Vol. 2, No. 18 (6 May 1985), pp.16-17.

4. Wilson, Gecrge C. "Brand-New Engines Cannibalized to Keep F15s, F16s Flying." Washington Post, 28 February 1985, p. 19.

Official Documents

5. Air Force Logistics Command. History of the Air Force Logistics Command, (FY 1985). Wright-Patterson AFB, OH: HQ AFLC/HO. SECRET--Not Releasable to Foreign Nationals. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

6. Congress. (Senate Armed Services Committee). F-15 and F-16 Engine Problems. Hearing . . . 96th Congress, 1st session. Washington, Government Printing Office, 1980. 132p.

7. Tactical Air Command. History of the Tactical Air Command, (January-December 1980). Langley AFB, VA: HQ TAC/HO, May 1982. SECRET--Not Releasable to Foreign Nationals. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

CONTINUED

8. Tactical Air Command. History of the Tactical Air Command, (January-December 1983). Langley AFB, VA: HQ TAC/HO, May 1985. SECRET--Restricted Data. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

9. Tactical Air Command. History of the Tactical Air Command, (January-December 1984). Langley AFB, VA: HQ TAC/HO, December 1985. SECRET--Not Releasable to Foreign Nationals. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

10. Tactical Air Command. History of the Tactical Air Command, (January-December 1985). Langley AFB, VA: HQ TAC/HO. SECRET--Not Releasable to Foreign Nationals. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

11. US Department of the Air Force. San Antonio Air Logistics Center. F100 Engine Management Lessons Learned, prepared by Alvin B. Richter, Deputy Division Chief, Propulsion Management Division. Kelly AFB, TX: SA-ALC/MMP, December 1985.

12. US Department of the Air Force. San Antonio Air Logistics Center. F100 Engine Primary Power for F-15/F-16 Aircraft, briefing given by Lt Col Michael H. King to AFLC/CC. Kelly AFB, TX: SA-ALC/MMPMB, February 1985.

13. US Department of the Air Force. San Antonio Air Logistics Center. History of the San Antonio Air Logistics Center, (1 October 1979-30 September 1980). Kelly AFB, TX: October 1981. For Official Use Only. No FOUO information used from this source.

14. US Department of the Air Force. San Antonio Air Logistics Center. History of the San Antonio Air Logistics Center, (FY 1981-1982). Kelly AFB, TX. For Official Use Only. No FOUO information used from this source.

15. US Department of the Air Force. San Antonio Air Logistics Center. History of the San Antonio Air Logistics Center, (FY 1983). Kelly AFB, TX. For Offical Use Only. No FOUO information used from this source.

CONTINUED

16. US Department of the Air Force. San Antonio Air Logistics Center. Staff Summary Sheet, subject: F100 Engine Critical Parts Shortages, prepared by Lt Col Michael H. King for SA-ALC/CC. Kelly AFB, TX: SA-ALC/MMFMB, October 1984.

17. US Department of the Air Force. San Antonio Air Logistics Center. White paper documenting the F100 Readiness Team Working Group findings. Subject: Unique F100 Engine Design and On-Condition Maintenance Concept Require Specialized Logistics Support. Kelly AFB, TX: SA-ALC/MMPMB, 1985.

18. US Department of the Air Force. US Air Force Oral History Program. Interview with Ralph Fountain, Chief, Requirements and Distribution Branch, F-15 Acquisition Division, by Dr. Richard W. Iobst, Warner Robins Air Logistics Center/Office of History, 28 February 1980.

B. RELATED SOURCES

Articles and Periodicals

Pierce, James D. and Winfred E. Okumura. "New Technologies--Their Impact on Air Force Depot Repair." Air Force Jornal of Logistics, (Winter 1985), pp. 28-32.

Official Documents

Tactical Air Command. History of the Tactical Air Command, (January-December 1981). Langley AFB, VA: HQ TAC/HO, October 1983. SECRET--Not Releasable to Foreign Nationals. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

Tactical Air Command. History of the Tactical Air Command, (January-December 1982). Langley AFB, VA: HQ TAC/HO, February 1985. SECRET--Formerly Restricted Data. Classified by Multiple Sources. Declassify on OADR. Unclassified information only used from this source.

CONTINUED

US Department of the Air Force. Air Force Audit Agency. Report of Audit. Subject: Management of Flow Times and Floating Stock for Engines in Depot Repair. Project number 3030215, 29 June 1984.

US Department of the Air Force. San Antonio Air Logistics Center. F100 Engine Supportability Status Update, briefing given by Lt Col Michael H. King to Lloyd K. Mosemann, Air Force Deputy Assistant Secretary for Logistics and Communication. Kelly AFB, TX: SA-ALC/MMPMB, April 1985.

US Department of the Air Force. US Air Force Oral History Program. Interview with Kylf Dixon, Chief, F-15 Section, F-15 Missle and Helicopter Branch, F-15 Acquisition Division, by Dr. Richard W. Iobst, Warner Robins Air Logistics Center/Office of History, 26 February 1980.

US Department of the Air Force. US Air Force Oral History Program. Interview with Wade Carter, Chief, Engineering and Reliability Branch, F-15 Acquisition Division, by Dr. Richard W. Iobst, Warner Robins Air Logistics Center/Office of History, 26 February 1980.

US General Accounting Office. Report to the Chairman, Subcommittee On Defense, Committee On Appropriations, House of Representatives. Factors Limiting The Availability Of F-15 Aircraft At The 1st Tactical Fighter Wing. Washington, DC: Government Printing Office, 7 June 1982.

Other Sources

King, Michael H., Lt Col, USAF. Former F-100 Engine Propulsion System Manger, SA-ALC, Kelly AFB, TX. Telecon, 30 October 1987.

Sinclair, Donn. Local Representative, Production Support, Pratt and Whitney Aircraft, San Antonio, TX. Telecon, 30 October 1987.

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